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ABSTRACT

The purpose of this study was to investigate the differences and similarities in the performance of integrated science process skills among learners with differing cognitive-style preferences. In this study, two evaluative instruments were used. The first, the Learning-Style Inventory (LSI) was employed to measure individual cognitive styles. These were measured as two sets of dualities, i.e., perception types and processing types; their combinations resulted in four learning styles. The second evaluative instrument, the Test of Integrated Process Skills II (TIPS II) was used to assess five integrated process skills in science. They were: (1) stating hypotheses; (2) identifying variables; (3) operationally defining and designing investigation; (4) graphing; and (5) integrating data. These tests were administered to 107 college students who were elementary school education majors. Significant relationships (differences and correlations) were found between the cognitive-style preferences and the performance of integrated science process skills. Similarities in the performance of integrated science process skills were also found among students having different cognitive-style preferences. Cognitive-style preferences in the processing of information (reflection or action) were not significantly related to the performance of integrated science process skills. (Author/TW)

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A STUDY OF THE RELATIONSHIP BETWEEN
COGNITIVE STYLES AND INTEGRATED SCIENCE PROCESS SKILLS

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A STUDY OF THE RELATIONSHIP BETWEEN
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ABSTRACT

The purpose of this study was to investigate the differences and similarities in the performance of integrated science process skills among the learners divided by their cognitive-style preferences.

In this study, two evaluative instruments were used. The first, the Learning-Style Inventory (LSI) was used to measure individual cognitive styles. Cognitive styles were measured as the two sets of dualities, which were perception types and processing types and their combinations resulting in four learning styles. The second, The Test of Integrated Process Skills II (TIPS II) was used to assess five integrated process skills in science. They were: stating hypotheses, identifying variables, operationally defining, designing investigation, and graphing and integrating data. These tests were administered to one hundred and seven college students, who were elementary school education majors.

Significant relationships (differences and correlations) were found between the cognitive-style preferences and the performance of integrated science process skills. Among the students by their perception types, abstract conceptualization type students out-performed concrete experience type students, and the more students prefer abstract conceptualization, the better they perform on the overall tasks of integrated science process skills and a particular task of process skills, but not others, such as graphing and interpreting data. It could be concluded that overall performance of integrated science process skills and a particular type of science process skill such as graphing and interpreting data might be influenced by the cognitive-style preferences in the ways of perceiving information (concreteness or abstractness).

Similarities in the performance of integrated science process skills were also found among students having different cognitive-style preferences. Cognitive-style preferences in the ways of processing information (reflection or action) were not significantly related to the performance of integrated science process skills. Neither learning styles were, which were combinations of perception type and processing type. Furthermore, similar patterns in the TIPS II subscale score distribution were found among the students having different cognitive-style preferences. The common tendencies, in that the score for identifying variables was the lowest and for designing investigations was the highest, were found in every group.

The implications of these results were discussed. It is very necessary to consider the individual differences in cognition, such as cognitive styles, in science teaching and learning context.

A Study of the Relationship Between Cognitive Styles and Integrated Science Process Skills

Introduction

Development of cognitive skills named as science process skills is one of the important goals of science education. According to Hodson (1988), a significant feature of most of the science curriculum development in the past quarter century was "a major shift of emphasis away from the teaching of science as a body of established knowledge toward science as a human activity, with increasing emphasis on experience of the processes and procedures of science" (p. 19). Toward a philosophically and pedagogically valid science curriculum, he concluded that careful consideration of the relationship between the nature of science (scientific knowledge and scientific methods) and the nature of learning (the methods of learning science) is needed.

Numerous kinds of empirical studies related to the characteristics of student and teacher, and instructional strategies in science learning context have been accumulated. In the field of research on the cognition of learner, there seems to be two major ways to look, the perspectives as cognitive power and as cognitive structure. In the perspective as cognitive power, mental ability is seen as primarily quantitative (how strong a learner's mental ability is) and the

emphasis is on individual differences. On the other hand, in the perspective as cognitive structure, mental ability is seen as primarily qualitative (organization of knowledge) and the emphasis is on universal similarities.

In the view of cognitive structure, most recently, Yeany, Yap, and Padilla (1984), and Yap and Yeany (1987) revealed the hierarchical relationship among scientific reasoning skills and integrated science process skills, both are equally considered to be important cognitive skills in science. These studies can provide some fine structure required to be helpful in instructional and curriculum sequencing decisions.

On the view of cognitive power, cognitive skills in science such as science process skills, scientific reasoning skills and problem solving ability have been widely measured for different groups of students in different context. It can be seen that student, classroom, and cultural/societal characteristics all have a bearing on the development of cognitive skills. Student variables such as age, prior experience, IQ, cognitive style, etc. might be potential determinants of cognitive skills in science (Lawson, Costenson, and Cisneros, 1986). The moderating effect of individual differences on science learning seems well described in general, however there still remain questions regarding the relative influence of specific differences and the extent to which differences can be accommodated through science instruction.

In this study, the third perspective on cognition called cognitive style which focuses on the ways that mental ability is used by individuals is considered in terms of the individual differences in the performance of science process skills. Although less attention has been given in this view of cognitive styles, Ronning, McCurdy and Ballinger (1984) argued that the theory of problem-solving instruction must take into account individual differences (cognitive styles) among problem solvers as well as problem-solving methods and degree of knowledge acquisition. Through the meta-analysis of cognitive preferences and learning, Tamir(1985) indicated that cognitive preferences make significant contributions to learning, and that their inclusion in further educational research, as well as their consideration in educational practice, is to be encouraged.

Background and Purpose of this Study

The purpose of this study is to investigate the differences and similarities in the performance of integrated science process skills among the learners divided by their cognitive-style preferences.

Cognitive Styles

Cognitive styles are considered as consistent individual differences in the preferred ways of perceiving and processing information (Messick, 1976). Numerous different kinds of cognitive styles have been investigated. Although the perspectives and concept labels used in these studies are different, there still exist commonalities. All of these studies appear to deal with how individuals take in information or react to external stimuli and what they do with the information once the stimuli are acknowledged. This is considered to be a fundamental aspect of cognition and learning. In this study, the following Kolb's definition is accepted as a cognitive style.

Kolb (1979, 1984) defined cognitive style as a combination of how individuals perceive and process information. The abstract/concrete dimension (perception type) is representing two opposed ways of grasping experience either through reliance on conceptual interpretation and symbolic representation

(thinking), or tangible and felt qualities of immediate experience (sensing/feeling). The active/reflective dimension (processing type) is representing two opposed ways of transforming figurative representation of experience either through internal reflection (watching), or active external manipulation (doing). These two dimensions correspond directly to Piaget's figurative and operative aspect of thought.

In considering the linkage between cognitive style and cognitive power, Kogan (1973, 1976) noted that cognitive style measures fall into two groups. The first group includes tests that measure specific skills and abilities. Scores on these tests tend to be correlated with scores on IQ tests. These definitions of style bridge the gap between a study of perception and a study of cognitive power. The second group includes tests that measure preferences. Scores on these tests tend to be much less strongly related to IQ scores. The results from these tests have been shown to be related to a variety of personality and social-emotional factors. These definitions of style might provide the link between personality traits and cognitive development. In this study, cognitive-style preference is measured by the Learning-Style Inventory (Kolb, 1976).

Science Process Skills

Science Process Skills, one of the cognitive skills in science are required in the process of problem solving in science. Referred to as the integrated science process skills, they include formulating hypotheses, operationally defining, controlling variables, planning investigations, and interpreting data (Livermore, 1964).

As early as the mid-1980's, Huxley, Hooker, and Henslow (Layton, 1973, p. 172) advocated the teaching of science processes in schools. In the past quarter century, science process skills have become major emphases of science curriculum development. The development of science process skills in students is considered to be a major goal of education by many educators (e.g., Gagne, 1965; Hernon, 1970; Neie, 1972; Okey, 1972). Gagne (1965) contended that science process skills represent common elements in the scientific endeavor as well as carry the promise of broad transferability across many subject areas. Okey (1972) stated that a major goal of education should be "to teach students how to acquire and process information" (p. 57). Padilla (1980) gave the following reasons for the importance of science process skills activities: (1) the skills are generalizable, (2) the skills activities accurately reflect the nature of science, and (3) the skills activities involve the development of formal operational abilities.

Need for Study

The integrated science process skills have been shown to be important aspects of science learning and instruction. Numerous studies have been performed which evaluate the effects of various curricula and special instructional strategies on the acquisition of integrated science process skills. Results indicate that the integrated science process skills can be mastered if the learning activities are appropriately matched to the level of the learner. However, cognitive styles as individual differences in the ways of thinking have been ignored in these studies. There still remain questions regarding the influence of specific differences and the extent to which differences can be accommodated through science instruction. If it is true that learners' cognitive styles differ, especially if cognitive styles cannot be changed or people cannot learn to use different styles in different context, then it would be futile to adopt a curriculum and instructional goal whose attainment assumes that everyone be able to think in a particular way, such as science process skills.

Thus, there appears to be a need for basic research to investigate the relationship between cognitive styles and integrated science process skills. As a first step, answers to the following questions are sought in this study.

- 1 What are the differences, if any, in the performance of integrated science process skills among learners who have different cognitive styles?
2. What are the similarities, if any, in the performance of integrated science process skills among learners who have different cognitive styles?

Previous Studies and Hypotheses Setting

In the field of research in science education, most of the studies of cognitive style related to cognitive skills in science tend to focus on the particular dimension of cognitive style, that is field-dependence/-independence, and its relationship with scientific reasoning skills. Too few studies have been done by looking for this or other dimensions of cognitive style related to integrated science process skills.

Cognitive Styles and Scientific Reasoning Skills

Scientific reasoning skills or formal operational thinking, derived from Piaget's intellectual developmental theory, are another cognitive skill that has been considered to be important by science educators. For example, Cohen (1980) noted that the simulation of students' formal reasoning or thinking ability represents a really worthwhile aim of science education. Lawson, Karplus, and Adi (1978) considered formal operational schemata to be important to the students' understanding of science content and the process of scientific investigation. The importance of the integrated nature of science process skills and scientific reasoning skills cannot be denied.

A review of the literature suggests that field-dependent/field-independent dimensions of cognitive style appears to be potential determinants of scientific reasoning skills. This function of cognitive style is "an ability to

break up an organized field in order to keep part of it separate from the field" (Witkin, Oltman, Raskin and Karp, 1971, p. 4). Case (1974), Niemark (1975), and Lawson and Wollman (1977) posed a theoretical link between cognitive style and formal operation of cognitive development. Karplus, Karplus, and Wollman (1978), and Linn (1978), indicated that cognitive style might influence some particular reasoning patterns such as proportional reasoning and controlling variables. Lawson (1976), Lawson and Wollman (1977), and Grippin and Yezzi (1983) reported significant correlations between formal operations and cognitive style.

The relative influence of specific differences including cognitive style on scientific reasoning skills were also reported. Sneider et.al. (1984) indicated that cognitive style, verbal IQ, and mental power were all significant predictors of success in controlling variables. Stuessy (1984, 1985) indicated that age and IQ were the strongest determinants of scientific reasoning skills followed by cognitive style, experience, and locus of control. Furthermore, in a comparative study of seventh grade students and college students, Lawson (1982) found differences in the relative contributions of intelligence, cognitive style, prior knowledge, and level of cognitive development. Cognitive style and prior knowledge were greater influential factors at the college level on scientific reasoning than at the seventh grade level.

Scientific Reasoning Skills and Science Process Skills

Several studies noted a high correlation between scientific reasoning skills and science process skills. Padilla, Okey, and Dillashaw (1983) found a r value (correlation coefficient) = .73; Tobin & Capie (1981) reported $r = .60$. Both studies worked with middle and secondary students. Walkoss and Yeany (1984) found $r = .47$ with college students. Furthermore, Yeany, Yap, and Padilla (1984) and Yap and Yeany (1987) indicated the subordinate and superordinate relationships among these two sets of cognitive skills in science. Scientific reasoning skills and integrated science process skills are considered to be interrelated with each other.

Cognitive Styles and Science Process Skills

Few studies seeking for the influence of field-dependence/field-independence dimensions of cognitive style on science process skills have been done. For example, Devore (1984) reported that cognitive style and dogmatism were strongly related to science process skills, while propositional logic ability, background in science, and age were not strongly related. Other dimensions of cognitive style such as learning styles, problem solving styles, cerebral hemisphere preferences, etc., related to science process skills or scientific reasoning skills were found in too few studies to establish a pattern.

The majority of studies support the evidence which indicates a relationship between field-dependent/field-independent dimensions of cognitive style and scientific reasoning skills, and also a relationship between scientific reasoning skills and integrated science process skills. Therefore, although few studies have been done by looking for the direct influence of this dimension of cognitive style on science process skills, a relationship between cognitive style and integrated science process skills might be theoretically and empirically predictable. Yet, these previous studies provide a rather limited basis in a search for a relationship between cognitive styles including other dimensions besides field-dependence/-independence and integrated science process skills. It may be that looking for relationships between the cognitive styles (skills and/or preferences) and performance of integrated science process skills is a needed area of research in science education.

In this study, the following hypotheses are tested:

1. There will be significant ($p < 0.05$) differences in the performance of integrated science process skills related to the cognitive styles of learners;
2. There will be significant ($p < 0.05$) correlations between cognitive styles and integrated science process skills;
3. There will be similar or consistent patterns in the performance of integrated science process skills among the different cognitive-style learners.

Design and Procedures

In order to attain the purpose of this study, two evaluative instruments were used. The first, the Learning-Style Inventory (LSI), developed and revised by Kolb (1976), consists of nine items designed to measure individual cognitive styles. The instrument is a self-description questionnaire of nine items requiring respondents to rank-order four words in a way that best describes their learning styles. One word in each item corresponds to one of the four learning modes: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). The LSI measures an individual's relative emphasis on each of these modes and also two derived scores that indicate the extent to which an individual emphasizes abstractness over concreteness (AC-CE, perception types) and action over reflection (AE-RO, processing types). Norms are available for adults aged 18 to 60.

Reported validity studies have relied on correlations with other instruments. For example, correlations between the LSI and Meyers-Briggs Type Indicator (MBTI) showed strong and consistent relationships between the concrete/abstract and feeling/thinking dimensions and between active/reflective and extroversion/introversion dimensions (Kolb, 1976, 1984). The MBTI is designed to assess the Jungian types of extroversion/introversion, sensation/intuition, thinking/feeling, and judging/perceiving as cognitive styles (Meyers-Briggs, 1975).

The LSI showed consistent split-half reliabilities for the derived scores, (AC-CE, and AE-RO) averaging .80. Kolb (1976) concluded that the derived scores are reliable measures for research applications.

The second, the Test of Integrated Process Skills II (TIPS II), developed by Burnes, Wise, and Okey (1982), consists of thirty-six items designed to assess five integrated process skills in science. They are stating hypotheses (nine items), identifying variables (twelve items), operationally defining (six items), designing investigation (three items), and graphing and interpreting data (six items). The questions are answered through multiple choice selection of four possible answers. Estimated readability level for the TIPS II test is 9.5 (FOG) and it is available for seventh to twelfth grades or higher.

Total test reliability, using Cronbach's Alpha, was measured at .86. The point biserial discrimination indices ranged from .11 to .64 with a mean of .35. Item difficulty indices ranged from .15 to .87 with a mean of .53 (Burnes, Wise, and Okey, 1983). Correlation between the total TIPS II score and the total score of the Group Assessment of Logical Thinking (GALT) was significantly strong at .71. The GALT test is designed to assess six reasoning skills. They are: conservation, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Roadrangka, Yeane, and Padilla, 1983). The TIPS II test is considered to be a reliable instrument for assessing students' competence in the integrated science process skills.

The population of the sample for this study consisted of one hundred and seven college students which included one hundred and four females and three males, who were elementary school education majors and participated in the "Teaching Science in the Elementary School" course in the undergraduate program of Science Education. Both tests were administered to these students on August 27, 1987.

Results of Data Analyses and Hypotheses Testing

The data on the results of the LSI questionnaire are shown in Table 1. Based on the number of students classified by their cognitive styles, the differences in frequency distribution among the cognitive-style students were examined by the Chi-Square test. Significant differences ($p < 0.05$) were found in the numbers of students divided by their perception types (concrete experience and abstract conceptualization), and processing types (reflective observation and active experimentation). The majority of the students were concrete experience type ($N=80$, 74.8%), and also reflective observation type ($N=68$, 63.6%). However, there were no significant differences among the number of students divided into each of four learning styles, which was a combination of perception type and processing type.

The data on the results of the TIPS II test are shown in Table 2. Differences in the TIPS II total and subscale scores among the cognitive-style students were examined by the Analysis of Variance (ANOVA). The ANOVA results are summarized in Table 3. Significant differences ($p < 0.05$) in the TIPS II total and subscale scores were found between the students divided by their perception types. Abstract conceptualization (AC) type students significantly out-performed concrete experience (CE) type students on the TIPS II total and one of the subscales: graphing and interpreting data. However, no significant differences were found in the other four subscale

scores between these perception-type students. On the other hand, between the students by their processing types, which were the other dimension of cognitive styles, no significant differences were found in the TIPS II total and subscale scores. Among the four groups by their learning styles, no significant differences were found in each of these scores. Therefore, hypothesis 1: there would be significant ($p < 0.05$) differences in the performance of integrated science process skills related to cognitive styles of learners, was partially, but not totally, supported by these results.

Correlations between the TIPS II scores and the LSI derived scores (AC-CE, and AE-RO) were analyzed. The results of correlation analyses (Pearson product-moment correlation coefficient) are summarized in Table 4. Significant correlations were obtained between perception-type score (AC-CE) and the TIPS II total score ($r=0.23$, $p < 0.01$). This result indicates that the more students prefer abstract conceptualization to concrete experience, the better they perform on the overall test of integrated science process skills. Similarly, significant correlations were obtained between perception types and one of the process skills, graphing and interpreting data ($r=0.20$, $p < 0.05$). The other four process skills of the TIPS II subscales were not related to students' perception types. On the other hand, processing types (active experimentation and reflective observation) were not related to the TIPS II total and four subscale scores, except one. That is, significant correlations were obtained between

processing-type score (AE-RO) and the TIPS II subscale score of operationally defining ($r = 0.20$, $p < 0.05$). Therefore, hypothesis 2: there would be significant ($p < 0.05$) correlations between cognitive styles and integrated science process skills, was partially, but not totally, supported by these results.

Similarities in the performance of integrated science process skills were also found among students who had different cognitive styles. In addition to the results that cognitive styles are not always significantly related to the performance of integrated science process skills, similar tendencies to the score distributions of five subscales of the TIPS II test were found in every group divided by each cognitive-style type. In each group, the score for the process skill of designing investigation was the highest, and the score for identifying variables was the lowest. The scores for the other three process skills: stating hypotheses, operationally defining, and graphing and interpreting data were intermediate. These tendencies were commonly found in every group by cognitive-style types, and total group. Therefore, hypothesis 3: there would be similar or consistent patterns in the performance of integrated science process skills among the different cognitive-style learners, was qualitatively supported by these results.

Summary and Conclusion

In this study, the differences and similarities in the performance of integrated science process skills related to the cognitive-style preferences of learners were investigated.

These results are summarized as follows:

1. Cognitive-style preferences are different among students.

The majority of the students were concrete experience type on perception dimension, and reflective observation type on processing dimension of cognitive styles.

2. Particular cognitive-style preferences are significantly related to the total performance of integrated science process skills.

On the perception dimension of cognitive styles, abstract conceptualization type students out-performed concrete experience type students, and the more students prefer abstract conceptualization, the better they perform on the overall test of integrated science process skills. However, on the processing dimension of cognitive styles, no such kinds of pattern were found.

3. Particular cognitive-style preferences are significantly related to the performance of some particular type of process skills, but not others, such as graphing and interpreting data, and operationally defining.

On the perception dimension of cognitive styles, abstract conceptualization type students out-performed concrete experience type students, and the more students prefer abstract conceptualization, the better they perform on the tasks of graphing and interpreting data. On the processing dimension of cognitive styles, the more students perform active experimentation to reflective observation, the better students perform on the tasks of operationally defining, while no significant differences in the performance were found between two types. No such kinds of pattern were found on the other tasks of science process skills related to cognitive-style preferences.

4. Cognitive-style preferences are not always significantly related to the performance of integrated science process skills.

No significant relationships (differences and correlations) were found between processing types of cognitive styles and the TIPS II total and four subscales, but operationally defining. No significant relationships (differences and correlations) were found between perception types of cognitive style and the four subscales of the TIPS II test, but graphing and interpreting data. Furthermore, learning styles, which were a combination of perception types and processing types, were not significantly related to the performance of integrated science process skills.

5. There is a similar or consistent pattern in the performance of integrated science process skills among the different cognitive-style students.

Common tendencies to the score distributions of five subscales of the TIPS II test were found in every group divided by each cognitive-style type. The score for identifying variables was the lowest and for designing investigation was the highest in every group.

Based on these results, it could be concluded that overall performance of integrated science process skills might be influenced by the cognitive-style preferences in the ways of perceiving information (concreteness or abstractness), rather

than in the ways of processing information (reflection or action). In addition to this, it could be concluded that performance of a particular type of science process skill, but not others, such as graphing and interpreting data, might be influenced by the perception-type preferences (abstract/concrete) as cognitive styles.

Discussion and Implication

In terms of the definition of cognitive styles and its linkage with cognitive power, Kogan (1973, 1976) indicated that cognitive styles measured as preferences tend to be much less strongly related to cognitive power than cognitive styles measured as skills do. This study shows that preferences in perception (abstract/concrete) as cognitive styles were significantly related to science process skills. Several previous studies indicated that perceptual-skills (field-independence/-dependence) as cognitive styles are related to scientific reasoning skills, and might be related to science process skills. It might imply that science process skills might be related to perception styles as skills and/or preferences. Relative influences of these two specific differences in perception styles are not known. Preferences in perception might be related to cognitive developmental level or scientific reasoning skills.

On the other hand, this study also shows that preferences in processing (active/reflective) were not significantly related to the performance of integrated science process skills. Neither learning styles were, which were combinations of perception type and processing type. Furthermore, common patterns in the TIPS II subscale score distribution were seen among the different cognitive-style students. Wallach and Kogan (1965) indicated that cognitive-style preferences are related to a variety of personality and social-emotional factors. So, perhaps it is

appropriate to think of these results as providing the link between personality and cognitive development. It might be that college students have already developed their science process skills well enough to operate, or they have already developed their cognitive structure which makes the operation of integrated science process skills possible, so that the performance of those skills does not depend on whether they prefer a particular style or not. These results might imply that there exist the universal cognitive structure behind the performance of science process skills, although cognitive-style preferences are different among students, and performance levels of each science process skill might be different among students who have different cognitive-style preferences.

Kolb's cognitive-learning style model as a combination of how individuals perceive and process information was accepted in this study. Kolb (1984) noted that the abstract/concrete dimension (perception type) is representing the ways of grasping experience either through reliance on conceptual interpretation (thinking) or immediate experience (sensing/feeling). The active/reflective dimension (processing type) is representing the ways of transforming experience either through internal reflection (watching) or active external manipulation (doing). This is considered to be a fundamental aspect of cognition and learning in that how individuals take in information or react to external environment and what they do with the information once the stimuli are acknowledged. On the science teaching and learning context, it is very necessary to develop the students'

cognitive skills in science by letting them have first hand experience with real objects and understand the concepts from real things and phenomena through observation and experimentation. Therefore, neither of modes, abstract conceptualization or concrete experience, and active experimentation or reflective observation, is completely exclusive of the other. Both modes are considered to be important, especially in learning science.

This study shows the correlations that the more students prefer abstract conceptualization to concrete experience, the better they perform on the overall tasks and a particular task of integrated science process skills. The more students prefer active experimentation to reflective observation, the better they perform on a particular task of science process skills. In the interpretation of these results, it is important to notice that correlation do not always mean cause-effect relationship. It is not known whether cognitive-style preferences affect science process skills or vice versa. It might be that cognitive styles and integrated science process skills are interrelated with each other, or not. To attain the goal, development of cognitive skills in science, there appear to be a lot of research questions to find out.

In this study, individual differences in the performance of integrated science process skills were investigated in terms of the cognitive-style preferences of learners as a selected internal cognitive factor. There still exist a series of basic questions, as discussed here, regarding the linkage among

cognitive style, cognitive power, cognitive structure, and other internal and external variables. It is not known, what is different, what causes the differences, and how and to which extent differences can be accommodated through instruction. There exists no single theory. Thus, there appears to be a need for further continuous studies. Implications into science teaching and learning seem to be fundamentally important in a careful consideration of the relationship between the nature of science (scientific knowledge and scientific methods) and the nature of learning (methods of learning science), toward a more philosophically and pedagogically valid science curriculum.

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APPENDIX

Table 1. Results of the LSI Questionnaire:

Number of Students by Cognitive-Style Preferences

		PROCESSING TYPES		TOTAL
		REFLECTIVE OBSERVATION (RO)	ACTIVE EXPERIMENTATION (AE)	
PERCEPTION TYPES	CONCRETE EXPERIENCE (CE)	STYLE I N=49 (45.8%)	STYLE IV N=31 (29.0%)	N=80 (74.8%)
	ABSTRACT CONCEPTUALIZATION (AC)	STYLE II N=19 (17.8%)	STYLE III N= 8 (7.5%)	N=27 (25.2%)
TOTAL		N=68 (63.6%)	N=39 (36.4%)	N=107 (100%)

Table 2. Results of the TIPS II Test:

Means and Standard Deviations of Integrated Science Process Skills
by Cognitive-Style Preferences

COGNITIVE-STYLE TYPES	TEST OF INTEGRATED PROCESS SKILLS (TIPS II)					
	TIPS TOTAL (36)	SUBSCALES				
		T1 STATING HYPOTHESES (9)	T2 IDENTIFYING VARIABLES (12)	T3 OPERATIONALLY DEFINING (6)	T4 DESIGNING INVESTIGATION (3)	T5 GRAPHING & INTERPRETING DATA (6)
TOTAL GROUP (N=107)	26.0561 4.8967	6.5794 1.7539	7.8037 2.6258	4.5794 1.1577	2.6262 0.5912	4.4673 1.2078
PERCEPTION TYPES						
CONCRETE EXPERIENCE (STYLE I&IV: N=80, 74.8%)	25.4750 4.8443	6.4000 1.7546	7.6750 2.5297	4.4750 1.1360	2.6000 0.6080	4.3250 1.1338
ABSTRACT CONCEPTUALIZATION (STYLE II&III: N=27, 25.2%)	27.7778 4.7258	7.1111 1.6718	8.1852 2.9094	4.8889 1.1875	2.7037 0.5417	4.8889 1.3397
PROCESSING TYPES						
REFLECTIVE OBSERVATION (STYLE I&II: N=68, 63.6%)	25.8088 5.4697	6.6029 1.9172	7.6765 2.8149	4.4706 1.1904	2.5735 0.6305	4.4853 1.2870
ACTIVE EXPERIMENTATION (STYLE III&IV: N=39, 36.4%)	26.4872 3.7196	6.5385 1.4482	8.0256 2.2767	4.7692 1.0873	2.7179 0.5104	4.4359 1.0710
LEARNING STYLES						
STYLE I (N=49, 45.8%)	24.9388 5.4253	6.3469 1.9424	7.5306 2.7318	4.2449 1.1093	2.5510 0.6475	4.2653 1.1686
STYLE II (N=19, 17.8%)	28.0526 5.0495	7.2632 1.7270	8.0526 3.0637	5.0526 1.2236	2.6316 0.5973	5.0526 1.4327
STYLE III (N= 8, 7.5%)	27.1250 4.0861	6.7500 1.5811	8.5000 2.6726	4.5000 1.0690	2.8750 0.3536	4.5000 1.0690
STYLE IV (N=31, 29.0%)	26.3226 3.6732	6.4839 1.4346	7.9032 2.1963	4.8387 1.0984	2.6774 0.5408	4.4194 1.0886

Table 3. Summary of a One-Factor Analysis of Variance (F-values):
The TIPS II Scores by Cognitive-Style Preferences

	Cognitive-Style Differences		
	Perception-Type Differences (df=1, 105)	Processing-Type Differences (df=1, 105)	Learning-Style Differences (df=3, 103)
TIPS II Total Score	CE < AC * (4.61)	NS (1.91)	NS (2.12)
T1. Stating Hypotheses	NS (3.38)	NS (0.03)	NS (1.30)
T2. Identifying Variables	NS (0.76)	NS (0.44)	NS (0.43)
T3. Operationally Defining	NS (2.57)	NS (1.68)	NS (3.17)
T4. Designing Investigations	NS (0.57)	NS (1.60)	NS (0.86)
T5. Graphing & Interpreting Data	CE < AC * (4.49)	NS (0.04)	NS (1.98)

NS: not significant
* p<0.05

Table 4. Summary of a Correlation Analysis (r-values):

Correlation Coefficients among The TIPS II Scores and LSJ Scores

	LSJ Derived Scores	
	Perception-Type Score (AC - CE)	Processing-Type Score (AE - RO)
TIPS II Total Score	0.23 **	0.05
T1. Stating Hypotheses	0.05	-0.01
T2. Identifying Variables	0.14	0.01
T3. Operationally Defining	0.14	0.20 *
T4. Designing Investigations	0.11	0.06
T5. Graphing & Interpreting Data	0.20 *	-0.01

* $p < 0.05$

** $p < 0.01$